Proceedings of the 9th Global Public Health Conference, Vol. 9, Issue 1, 2026, pp. 47-68

ISSN 2613-8417 online
DOI: https://doi.org/10.17501/26138417.2026.9104

INNOVATIVE TECHNOLOGIES TO IMPROVE INFECTION PREVENTION AND CONTROL IN SOUTH AFRICAN HEALTHCARE FACILITIES FACING WATER SCARCITY

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Abstract: Background: Water is the most essential yet overlooked resource. Clean water, sanitation, and hygiene in healthcare facilities improve public health and community resilience during disease outbreaks. In water-scarce healthcare facilities, current technology must improve infection prevention and control (IPC). South Africa must address and manage challenges in healthcare facilities while implementing digital health and technology innovations to ensure IPC compliance during water scarcity. **Aim:** This study aims to evaluate the effective digital and technological innovations to improve infection prevention and control (IPC) practices for South African healthcare facilities experiencing water scarcity. **Method:** A comprehensive search was conducted in four databases: PubMed, EBSCOhost, CINAHL, and MEDLINE, according to the PRISMA guideline. Studies were published in English from 2020-2025. Data analysis was done systematically following Arksey & O'Malley's five-stage approach on existing literature. **Results:** The search retrieved 799 articles, of which 9 articles were eligible for review after screening. The identified and developed themes focused on best practices in technology advancements to improve IPC practices in healthcare facilities experiencing water scarcity. Three themes merged: 1) Waterless hygiene technologies, 2) Smart water management systems, and 3) Digital health tools to optimise IPC practice. These findings suggest integration of technological solutions to strengthen current IPC practices in healthcare facilities experiencing water scarcity. **Recommendations:** In the digital and technology era, healthcare systems depend on the integration of various technologies to improve IPC standards to ensure continuous healthcare services amid water outages or persistent water shortages.

Keywords: Technology innovations, infection prevention and control, water-scarcity, healthcare facilities

1. Introduction

In this era of the 21st century, African countries, including South Africa, are facing water scarcity. Resulting in water service in healthcare facilities being nearly impossible, particularly in remote areas. Digital technology has garnered attention across domains for the past decade, although it is new in the healthcare domain, particularly in some parts of South Africa. Incorporating effective innovation technologies in healthcare facilities experiencing water scarcity can improve infection prevention and control (IPC) practices.

Water scarcity is caused by climate change, extreme weather, population increase, rapid urbanization, aging healthcare infrastructures, and poor water supply system maintenance (Mathivha et al., 2025). Water scarcity in healthcare facilities exposes nurses, patients, and the community to health risks,

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particularly if IPC standards are not observed (Alhumaid et al., 2021). The context of water scarcity, the basic hygiene practices and general cleanliness of the facilities are compromised, resulting in transmission of healthcare-acquired infections (HAIs). These infections are a result of inadequate handwashing, poor sanitation, and an unhygienic environment. These compromised IPC practices and poor sanitation as a result of water scarcity directly affect patient outcomes and safety.

The gap between current IPC practices and the technological solutions for water scarcity in areas like South Asia, parts of the Middle East and sub-Saharan Africa is significant (Wah, 2026). Current practices often lack the necessary technology to effectively manage water scarcity, resulting in a lack of sustainable solutions. A study by Wah (2026) highlights that smart water management systems and artificial intelligence (AI) driven technologies are implemented to address the water scarcity gap in developed countries. Different nations, including the United States of America (USA), Germany, and Brazil, have incorporated smart features and sustainable designs in innovative approaches to improve water supply (Ssekyanzi et al., 2024). These countries are progressing towards achieving universal access to basic water services, sanitation, and hygiene (WASH) for all, including in healthcare facilities by 2030 (WHO, 2025; du Plessis, 2023).

Compared to China, the Middle East, and western regions, technological progress has proven to influence water supply in under-resourced areas by increasing water consumption, including recyclable technologies (Jiang et al., 2025). According to the United Nations (UN), China is amongst 13 countries that are experiencing water scarcity, and this is an acute crisis for it (Jiang et al., 2025). However, the existing research has not addressed how technology innovations can be used in healthcare facilities experiencing water scarcity to improve IPC.

To improve patient safety and quality care, the Ugandan Ministry of Health has included rainwater harvesting technologies and solar-powered water pumping systems in its WASH policy (WaterAid Uganda Country Programme Strategy 2023–2028, 2023). The innovations were beneficial when combined with hygiene behaviour change to minimize healthcare facility hygiene-related mortality. Similarly to Bangladesh, it has placed a high priority on funding community-based solutions by sharing hygiene information from nurses using digital training tools to improve patient care during water scarcity (Siddique, 2021). This digital innovation has improved nursing care and influenced the delivery of care in the context of water scarcity in primary healthcare clinics (Siddique, 2021).

In South Africa, the Department of Health and international organisations have used boreholes and refilling tankers to ensure IPC compliance in healthcare facilities during water scarcity (Jiyane & Khunou, 2023; Van der Heijden et al., 2022). These water supply techniques are ineffective and contribute to water scarcity due to infrastructural constraints, including aging buildings, leaking taps, and electrical interruptions, or load-shedding, making it impossible to pump water from the source to the facility. South Africa's efforts are much less effective than those of other developed nations like the US, Singapore, Saudi Arabia, and Australia because these systems lack the technological support to consistently supply water to healthcare facilities (Thenga & Nzama, 2025).

Therefore, this study aims to close the literature gap by addressing the research question: What are the effective innovative technologies to improve IPC practices for South African healthcare facilities experiencing water scarcity?

2. Materials and Methods

2.1 Study design

This study employed a scoping review approach, which examined the wide range of the published scientific literature on the existing innovative technologies to improve IPC practices in South African healthcare facilities experiencing water scarcity. The review was inspired by Arksey and O'Malley's five-stage approach and principle of synthesizing knowledge, which was established by Grimshaw (Fasugba et al., 2025). The stages are as follows: 1) Identifying the research question; 2) Identifying relevant results; 3) Selecting studies; 4) Charting data; and 5) Reporting results (Fasugda et al., 2025).

Step 1: Research question

What are the effective innovative technologies to improve IPC practices for South African healthcare facilities experiencing water scarcity?

Step 2: Identifying relevant results

This study used a search strategy and eligibility criteria to select the appropriate published articles to be used. The PPC framework was established, which means P-Population, C-Content, and C-Context. The population comprised healthcare facilities, content referred to technological innovations, and context referred to water scarcity. We limited our search to articles published in English between 2020-2025. A comprehensive search was conducted from four electronic databases, namely: PubMed, EBSCOhost, CINAHL, and MEDLINE. The search strategy comprised keywords, MeSH, and databases. The keywords used were: technology innovations, infection prevention and control practices, water-scarcity, and healthcare facilities. A search strategy using Medical Subject Headings (MESH) and text words was developed for each keyword and database. See Table 1 below for detailed information on the database search strategy. Each search employed a unique strategy.

Table 1: Search strategy based on alternative keywords

Search string	**Database**	**Limiters**
(technological innovation) OR (technological advancement)) AND (water scarcity)) OR (water shortage)) OR (water crisis)) AND (healthcare)) OR (health care)) OR (health facilities) AND (infection prevention and control measures)	PubMed	2020-2025

(technological innovation or technological advancement) AND (mitigation or prevention or reduction) AND (water scarcity or water shortage or water crisis) AND (healthcare or health care or hospital or health services or health facilities)	EBSCOhost Basic/Advanced	2020-2025
(technological innovation or technological advancement) AND (water scarcity or water shortage or water crisis) AND (healthcare or health care or hospital or health services or health facilities) AND (infection prevention and control measures)	CINAHL	2020-2025
TX (technological innovation or technological advancement) AND TX (water scarcity or water shortage or water crisis) AND TX (healthcare or health care or hospital or health services or health facilities)	MEDLINE Advanced search	2020-2025

The article had to meet an inclusion criterion to be included in the study. For inclusion, the study had to: 1) be published in English 2) be published in the last 5 years, from 2020 to 2025, 3) Be accessible as a full text, 4) The study focused on innovative technologies to improve IPC in healthcare facilities, 5) and the study had to be peer-reviewed.

Meantime, the exclusion criteria applied were as follows: 1) Any study that did not recommend digital and technological innovations to improve IPC in healthcare facilities, 2) studies that were not published in English, 3) older studies that were published before 2020, 4) Grey literature, guidelines, editorials, or any other literature that was not peer reviewed. 5) Studies with unavailable full text or incomplete data.

Step 3: Selecting studies

The search retrieved 799 articles. After a comprehensive review of the titles, abstracts, and admissible criteria, 9 articles were eligible for review (see Table 2). The articles were manually analysed and populated in a PRISMA diagram (See fig.1).

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Table 2: Summary of included studies

No	Author, Year	Study title	Country	Study aim	Study Approach	Recommendations
1	Mudenda, S., 2024	Infection prevention and control in low resource settings: opportunities for improvement.	Zambia	Exploring Infection Prevention and Control (IPC) practices in healthcare settings, especially in low-resource environments.	Systematic Review	Improved healthcare infrastructure is key to improving IPC in low-resource situations. This includes updating facilities for clean water, reliable energy, and sufficient ventilation. Hospitals and clinics should have isolation wards and autoclaves for cleaning medical tools to prevent cross-contamination. Improving hand hygiene can be promoted through low-cost interventions such as tippy taps (simple handwashing stations) in areas where water supply is limited. Also suggested using mobile apps to check hand hygiene compliance and electronic health information systems to track infection rates and antibiotic use. Telemedicine trains and supports remote or underserved healthcare workers in

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						IPC. Simple diagnostic techniques like rapid diagnostic tests (RDTs) can help diagnose infectious diseases early and prevent infection transmission. Electronic health records and health information exchanges help improve IPC education, training, and practices.
2	Siddique, I. M. (2021).	Sustainable water management in urban areas: Integrating innovative technologies and practices to address water scarcity and pollution. The Pharmaceutical and Chemical Journal.	Urban areas worldwide	The study examines a range of technologies and practices, including rainwater harvesting, greywater recycling, smart water grids, and advanced wastewater treatment.	Systemic Review	The integration of advanced technologies, such as smart water grids and advanced wastewater treatment, offers significant potential for improving water efficiency and reducing waste. These technologies enable real-time monitoring, adaptive control of water distribution, and the recycling of treated wastewater for non-potable purposes, contributing to a more circular economy. Furthermore, the incorporation of green infrastructure, such as rainwater harvesting systems, green roofs, and permeable pavements, not only reduces

						the burden on conventional water sources but also helps manage stormwater and mitigate urban runoff.
3	Matimolane, S., & Mathivha, F. I. (2025).	Tackling rural water scarcity in South Africa: climate change, governance, and sustainability pathways.	South Africa	Drawing on existing case studies, including Cape Town's "Day Zero" drought and the Greater Giyani Municipality, we highlight both current advances, such as smart metering, rainwater harvesting, and decentralized purification systems, and persistent vulnerabilities, including erratic rainfall, declining dam levels, and under-resourced infrastructure.	Case study	Many rural communities find rainwater collection tanks cost-effective and sustainable. For rural populations without electricity, solar-powered water purification technology and rainwater collection are reliable and sustainable. One example is the use of solar-powered reverse osmosis systems in remote areas of Limpopo and Mpumalanga, which help purify contaminated water and provide clean drinking water to off-grid communities. Smart technologies, such as AI-enabled leak detection, flow monitoring, and predictive analytics for drought response.

4.	Ssekyanzi, G., Ahmad, M. J., & Choi, K. S. (2024).	Sustainable solutions for mitigating water scarcity in developing countries: a comprehensive review of innovative rainwater storage systems.	Global	This review examines the potential of IRSSs to sustainably address rainwater challenges by analyzing key factors that influence their success.	Systemic Review	The innovations range from low-cost, locally available technologies, such as permeable pavements implemented in South Korea, to modern technologies such as green roof structures. These also include improved storage material, modular scalable systems, underground storage solutions, the smart city concept, and climate adaptive designs for which a multi criteria decision analysis is required for their application. The examples include systems that aid in increasing rainwater yield, aid in stormwater management, and innovative designs such as green roofs, permeable pavements, modular storage tanks, innovative stormwater systems for non-potable reuse, smart systems with sensors for optimized management, artificial ponds for flood control and agriculture, solar-powered purification for potable

						water, and gravity-driven systems to reduce energy consumption in water distribution
5.	Sridhar, L., Phadnis, R., Tiruchirapalli, K. S., Hussain, F., Kurumella, S. N. D., & Chappidi, S. C. (2024).	The Ideal Hand Hygiene Method in the Age of Water Scarcity: A Systematic Review and Meta-analysis.	Global	The search was conducted online on PubMed, looking for studies containing: Surgical hand rub, surgical hand scrub, SSIs, etc. A comparison was made between the waterless hand rub (with iodine, alcohol, or chlorhexidine) and a traditional hand scrub using soap and water.	Systemic review	Waterless hand rubbing is at least as effective as hand scrubbing in preventing SSIs and is a viable solution to address water scarcity concerns.
6.	Surendran, A., & Kaliyilil Ashokkumar, A. K. (2020).	Status of the Technology of Waterless Toilet Systems: An	International	In this thesis, waterless toilet technologies marketed by different manufacturers are deeply	Mixed-method	Waterless toilets are alternative solution which has been primarily used in the rural areas with water scarcity and environmental problems. Waterless

	International Outlook.	analysed and scaled the maturity level of technologies using the technology readiness level.	toilets are an alternative solution in rural areas with water shortages and environmental issues. Some types of waterless toilets are: • Ecosan-like composting toilets are preferred due to their similar principles. The garbage collector creates ashes by burning collected waste in the combustion chamber. • Incinerating Toilets: Dry toilets that burn feces instead of flushing them. Incinerating technology is the latest advancement in waterless toilet systems. • Electric Toilets: No water or plumbing required. Pressing start starts the incineration cycle after a flush. Foam flush toilets are suitable with composting because they clean the toilet bowl with each flush using only 3 Litres of water instead of 9 Litres. • Vacuum-flush toilets: These toilets use

						a section to remove feces and pee with little water. Due of their low flush water use, vacuum toilets are equally comfortable as flush toilets yet cost less. Evaporating toilets feature unique self-flushing technology.
7.	Kumar JS, Shobana D. (2024)	A study on assessment of rural health care system in India: schemes and implications.	India	This study aims to shed light on the state of rural healthcare infrastructure, the effectiveness of government healthcare initiatives, and the far-reaching implications for rural communities.	Review	These initiatives aim to raise the standard of healthcare services, accessibility, and infrastructure in rural areas: 1. Improve Health Information Systems, integrate telemedicine and technology. 2.Integrate Traditional and Modern Medicine 3. Strengthen Healthcare Infrastructure: Construct and renovate primary health centers and sub-centers, as well as other healthcare facilities
8.	Amuakwa-Mensah F, Klege RA, Adom PK, Köhlin G. (2021)	COVID-19 and handwashing: Implications for	Global	Primary health care as the main guarantor of a healthy population in the country and a global	Quantitative study	All public and private health care systems should incorporate nursing expertise in designing, generating, analysing, and applying data to support

		water use in Sub-Saharan Africa.		challenge in the world: a systematic review.		initiatives focused on social determinants of health and health equity using diverse digital platforms, artificial intelligence, and other innovative technologies.
9.	Abashidze-Gabaidze G, Khurtsia L, Gabaidze M, Loria L. (2024)	Primary health care as the main guarantor of a healthy population in the country and a global challenge in the world: a systematic review.	Global	This study aims to analyse the healthcare system and the existing gaps to develop strategies for improving PHC services.	Scoping review	Embrace technological innovations: Technological innovations, such as telemedicine and electronic health records, can potentially transform the delivery of primary health care services

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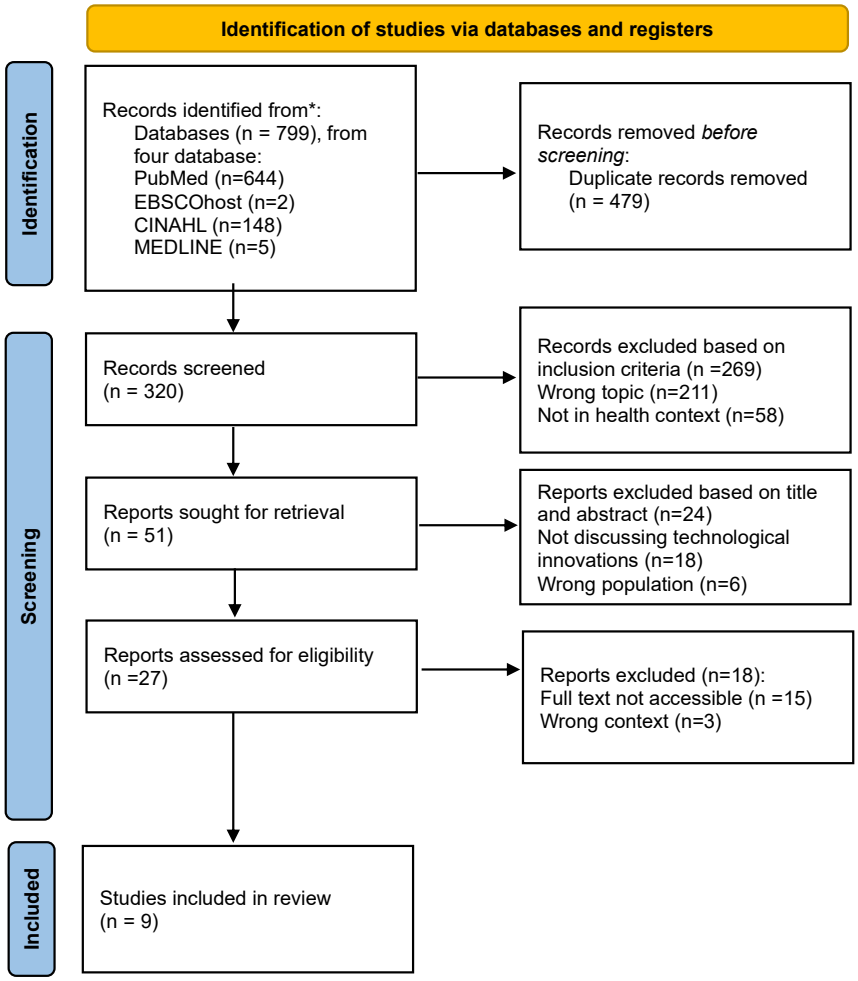

Figure1: PRISMA flow diagram (Adopted from Moher et al., 2009)

2:2 Data Analysis

Stage 4: Charting data

9 articles were retrieved for full text, and they were read and summarized in Table 2. The data extracted was analysed according to Arksey & O'Malley's recommendations. The synthesis and interpretation of the extracted data highlighted the technological innovations in place that are employed to improve the IPC practices in healthcare facilities facing water scarcity. Data was classified according to the author, publication year, study title, country, study aim, study approach, and recommendations. For each study, the reviewers discussed the technological innovations suggested until a consensus was reached. The reviewers maintained clear and transparent communication to reduce subjective biases.

3. Results and Discussion

In this section, the scoping review results will be reported, and the discussion will be summarized.

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A total of 799 articles from four databases were retrieved, of which 479 duplicates were removed (Fig. 1). The screening criteria were applied; 293 articles were excluded after screening for title and abstract. A total of 9 articles were retrieved for full text and analysed for recommendations on innovative technologies to improve infection prevention and control practices in South African healthcare facilities facing water-scarcity. During the analysis of the data, three themes and sub-themes were developed.

The following themes emerged:

Theme 1: Waterless hygiene technologies

Theme 2: Smart water management systems

Theme 3: Digital health tools to optimise IPC practice

Theme 1: Waterless hygiene technologies

Sub-theme 1: Waterless hand hygiene practice: Alcohol-based hand rub

The examined literature sought to describe how alcohol-based hand rubs are effective and cost-efficient in health settings experiencing water scarcity to ensure clean hands for quality patient care. Sridhar et al (2024) set out the significance of practicing handwashing using waterless strategies, including alcohol-based hand rub to curb HAIs that are transmitted by inadequate hand hygiene in a healthcare facility. This hygiene practice does not need water.

Sub-theme 2: Low-cost interventions for handwashing

In addition to this strategy, Mudenda (2024), had a common approach to minimizing the use of water during hand washing and promoted low-cost interventions such as tippy taps (simple handwashing stations) in areas where water supply is limited to ensure hygiene. This intervention is suggested to be developed at the community level, locally by members of the community, to support healthcare facilities, particularly in low-resource settings such as rural primary healthcare centres in ensuring hand hygiene during the water scarcity era (Mudenda, 2024).

Sub-theme 3: Waterless toilets

In the same way, Surendran et al (2020) suggested the use of waterless toilets to enhance IPC in healthcare facilities facing water scarcity. To improve sanitation in the regions lacking water, Surendran (2020) suggests that waterless toilets are in different models and each area should be adopted based on the technology they have. Waterless toilets are an alternative solution that has been primarily used in rural areas with water scarcity and environmental problems. Waterless toilets are an alternative solution that has been primarily used in rural areas with water scarcity and environmental problems. Surendran (2020) identifies different types of waterless toilets, some of which are: 1) Composting toilet, which is given more preference as its principle is the same as that of the ecosan. Is a waste collector where the collected wastes are then burned to ashes in the combustion chamber. 2) Incinerating toilets are dry toilet which burns the faeces instead of using water through flushing. The technology of incineration is

considered the most updated technology in the waterless toilet systems. 3) Electric toilets; their system doesn't require water, and there is no need for a plumbing connection. After a flush, pressing the start button will begin the incineration cycle. 4) Foam flush toilets; the foam mixture cleans the toilet bowl with every flush but uses only about 3 Litres of water instead of 9 Litres, making it fully compatible with the composting process. 5) Vacuum-flush toilets are flush toilets that use a vacuum for the removal of faeces and urine, resulting in a minimal requirement of water. Vacuum toilets provide the same level of comfort as traditional flush toilets, and they help save costs due to the minimised amount of flush water. 6) Evaporating toilets use an innovative self-flushing technology.

Theme 2: Smart water management systems

Sub-theme 1: Installation of Solar-powered systems

As seen in Table 2, several studies suggested the installation of solar power in the healthcare facilities to supply water during unreliable electricity supply. Ssekyanzi et al (2024) suggested the innovations that were low-cost and locally, these available technologies, such as permeable pavements implemented in South Korea, to modern technologies such as green roof structures. These are improved storage materials, modular scalable systems, underground storage solutions, and other climate-adaptive designs (Ssekyanzi et al., 2024). These systems aid in increasing rainwater yield, stormwater management, and innovative designs such as green roofs, permeable pavements, modular storage tanks, innovative stormwater systems for non-potable reuse, smart systems with sensors for optimized management, artificial ponds for flood control and agriculture, solar-powered purification for potable water, and gravity-driven systems to reduce energy consumption in water distribution (Ssekyanzi et al., 2024).

Improving solar energy is argued to be not just cost-effective but also beneficial in ensuring supplies that use electricity to supply water are functional at all times. A study conducted in South Africa suggested that the installation of rainwater harvesting tanks has proven to be a cost-effective and sustainable solution for many rural communities (Matimolane & Mathivha, 2025). In addition to rainwater harvesting, solar-powered water purification technologies are providing a reliable and sustainable solution for rural communities with limited access to electricity (Matimolane & Mathivha, 2025). One example is the use of solar-powered reverse osmosis systems in remote areas of Limpopo and Mpumalanga, which help purify contaminated water and provide clean drinking water to off-grid communities (Matimolane & Mathivha, 2025). Supply of potable water for drinking and hygiene practices is ideal for healthcare facilities.

Sub-theme 2: Smart meters and water harvesting devices

Advanced technologies, including smart meters and the installation of water harvesting supported by green energy is recommended to ensure that the water supply is consistent at healthcare facilities. A study conducted by Siddique (2021) suggested the integration of smart water grids and advanced wastewater treatment, which has the potential for improving water efficiency and reducing waste. These technologies are known to have enabled real-time monitoring, adaptive control of water distribution, and the recycling of treated wastewater for non-potable purposes, contributing to a more circular economy (Siddique, 2021). Furthermore, the incorporation of green infrastructure, such as rainwater

harvesting systems, green roofs, and permeable pavements, not only reduces the burden on conventional water sources but also helps to ensure the availability of water during droughts or extreme weather conditions (Siddique, 2021).

Theme 3: Digital health tools to optimise IPC practice

Sub-theme 1: Digital health tool

We are in an era of digital technology; the health sector is no exception. Studies have indicated that healthcare has improved through the integration of digital health and the utilisation of health platforms, tools, and artificial intelligence applications to improve patient care, particularly in healthcare facilities experiencing challenges of compromised care due to water scarcity (Abashidze-Gabaidze et al., 2024; Amuakwa-Mensah et al., 2021).

According to Abashidze-Gabaidze et al. (2024), embracing technological innovations such as telemedicine and electronic health records has the potential to transform the delivery of primary health care services. Similarly, Amuakwa-Mensah et al. (2021) attest that all public and private health care systems should incorporate nursing expertise in designing, generating, analysing, and applying data to support initiatives focused on social determinants of health and health equity using diverse digital platforms, artificial intelligence, and other innovative technologies. These suggestions, in the context of improving IPC practices in healthcare facilities experiencing water scarcity have the potential to improve patient outcomes.

4. Discussion

Improving healthcare infrastructure is vital to enhancing IPC in low-resource settings, particularly remote areas. Water is an essential resource needed in IPC to ensure good general hygiene practices. However, factors such as global change, ageing infrastructures, and maintenance backlogs contribute to healthcare facilities experiencing water shortages. Integration of technology into the existing water supply systems has the potential to improve IPC practices. Hand hygiene is a cornerstone of IPC practices and of waterless measures such as biodegradable disinfectant wipes, alcohol hand rub, sensor sanitizer dispenser technologies, and has the potential to reduce HAIs transmissions resulting from unhygienic hands in healthcare facilities.

4:1 Low-cost devices

Low-cost devices such as tippy taps (simple handwashing stations) are effective interventions that can be manufactured locally by community members to support healthcare facilities to ensure adequate handwashing during water outages or shortages. According to Ijaz et al (2021), community involvement in water projects is key, as community stakeholders collaborate with planners at all levels of water project planning in integrating technology. This participatory decision-making demonstrates support in implementing the interventions to mitigate water scarcity and improve hygiene in the healthcare facilities. The findings by Ijaz et al. (2021) indicate that the unhygienic conditions in the healthcare facilities might improve throughout the preparation and implementation of these strategies if

implementing authorities engage communities in the provision of water services, allowing community members, particularly if those in healthcare facilities, to express their ideas on their preferred technologies in water supply. Hence, certain innovative technologies may be ineffective for some facilities while being beneficial for others.

4:2 Collaboration to enhance sustainable technology

Literature indicates that the inclusion of end-user participation is essential during the planning and development of water access projects (Ijaz et al., 2021). Consequently, they will be able to advise on the most effective technology to be applied in their community, particularly with water strategies to improve IPC practices in healthcare facilities. The collaborative sharing of ideas and knowledge strengthens the relationship between water management providers and the end user to enhance handwashing, sanitation, and general cleanliness in healthcare facilities experiencing water scarcity (Mulopo & Chimbari, 2021). Additionally, Sharma et al (2024) are of the view that different government departments should collaborate with other sectors to ensure healthcare facilities have access to a reliable and sustainable technology to enhance water supply to improve IPC.

4:3 Renewable energy supply to aid the water supply

Healthcare facilities need a continuous and uninterrupted energy supply to maintain their operations. This energy is needed to aid water supply during water shortages, for example, by powering pressure pumps and other equipment that rely on electricity to supply water from Jojo tanks or pump water from underground to the facility (Mulopo & Chimbari, 2021). However, if this is interrupted, the services are affected. The switch to renewable energy sources, such as solar, thermal, and hydroelectric energy, in developing nations like China, Europe, Japan, and the USA, seems to be the most feasible approach to ensure IPC practices are adhered to, and quality care in healthcare facilities is rendered (Sharma et al., 2024). This is important in achieving global environmental and WASH sustainability. Sharma et al. indicate that solar systems can operate for over 25 years at 80% capacity in a healthcare facility, provided that proper operations, maintenance, and replacements are carried out (2024).

In the South African context, the adoption of solar energy for electrical supply in healthcare facilities, particularly in primary healthcare centres, would improve handwashing practices, sanitation, and hygiene, which wouldn't be compromised during power outages or load shedding, as it would ensure the availability of pumped water supplies in the facility.

Integrating telemedicine systems into primary healthcare services to facilitate patient care in the context of water scarcity has the potential to improve general patient care. In the instances where the facility is without water for hygiene practices, the healthcare workers, particularly nurses, would connect with the patient using digital technology, dispense treatment using smart dispensing tools at the shopping centres, with the patient receiving a secret PIN on the mobile device for collection. The AI-powered digital such as triaging device can be employed in emergency rooms or triage rooms to ensure that patients receive care without delay. Although these telemedicine systems and AI-powered digital tools may address the current challenge of compromised IPC in the facilities experiencing water scarcity, they might disrupt traditional healthcare services.

4:4 Barriers to implementing technology solutions in resource-limited settings

In contrast, while technological advancements can bring significant improvements in healthcare settings, patients have access to high-quality care and improved overall outcomes. Challenges of infrastructure could be cost-challenging in many low-resource regions. A study conducted by Lamichhane et al (2022) highlights that low and middle-income countries (LMICs) are still considered low-resource regions with geographical challenges, economic constraints, and poor access to basic infrastructures. Although Ferreira et al (2025) conducted a study in a different setting, the findings concluded that the infrastructure poses a significant barrier to implementing technology-enhanced solutions for high-quality healthcare in low-resource regions. While resource constraints remain a challenge, affordable adaptations to effective IPC practice, such as the use of alcohol hand rubs, offer a promising avenue to close gaps in hand hygiene practices.

Additionally, Lamichhane et al (2022) argued that different approaches for low-cost medical devices and healthcare solutions, including the use of smartphones for medical devices to monitor vital signs, can be used as an innovative solution for healthcare facilities experiencing water scarcity. However, some of the challenges faced in resource-limited settings include unreliable network coverage, intermittent or no electricity supply, and the affordability of healthcare in some low-resource settings. The efficiency of these technologies depends on skilled healthcare workers, the level of competence, and the availability of technology (Addotey-Delove et al, 2023).

The training of healthcare workers on the new technologies can be costly and time-consuming (Lamichhane et al., 2022), and training time interferes with patient care or can even take long. Some healthcare workers might find adaptation to these technologies challenging, placing further pressure on them. For instance, the use of traditional hygiene practices to incorporate a new technology to alleviate water scarcity can be frustrating to healthcare workers in low-resource settings. Addotey-Delove et al (2023) state that these technological innovations can challenge the different norms within communities and ethnic groups on privacy, confidentiality, and security. In Uganda, healthcare workers had to film their patients using mHealth (the use of mobile wireless technologies for health) to manage stroke; they felt uncomfortable and ended up not doing it anymore (Addotey-Delove et al., 2023). However, the effectiveness of these technologies in resource-limited settings would have a remarkable impact on patient care and improve IPC practices in the context of water scarcity.

4:5 Recommendations and Interventions

In healthcare facilities, hand washing, good sanitation, and general hygiene are linked to a standard practice of IPC. Integrating technologies into health is not only limited to practice but also improves IPC practices for healthcare facilities experiencing water scarcity. These innovative technologies are incorporated into various domains of IPC, such as handwashing, sanitation, and general cleanliness in healthcare. Patients won't experience substandard care due to water scarcity. For example, waterless hygiene practices, smart water management support, and digital health tools have the potential to improve the IPC practices and care patients receive. Ideally, most interventions can be beneficial in the IPC context; any practice will be supported by a referred technology.

4:6 Strengths and Limitations

This scoping review explored current innovative technologies aimed at improving IPC practices in healthcare facilities that are facing water-scarcity. The retrieved articles suggested various approaches for implementing different technologies to enhance water access and improve IPC practices. Despite rigorous analysis and the synthesis process used, certain limitations were considered. First, the selection and analysis of articles were done following selection criteria; however, the selection criteria were respected rigorously, and analysis was done systematically following Arksey & O'Malley's five-stage approach. Also, the process described in this paper was transparent to allow replication of the findings. However, the potential bias is that this review was limited to articles written in English; the exclusion of other papers limited the scope of this study. Therefore, the findings of this study cannot be generalised to a broader population because of the limited geographical scope of this review. However, this review aimed to evaluate the effectiveness of different technologies to improve IPC practices for South African healthcare facilities facing water-scarcity. Nonetheless, given the quantity of papers included and the similarities in the proposed technologies, a noticeable consistency in language is evident. Most of the studies examined were from the field of health around the globe. This indicates a common challenge that points toward a certain consensus globally.

5. Conclusion

This study supports the findings of the reviewed literature, indicating that integrating innovative technologies such as waterless devices for hand hygiene, sanitation, installation of smart water management systems, and digital tools has the potential to ease health systems and improve IPC practices in healthcare facilities during the water scarcity era. This literature review highlights the significance of these technologies and evaluates their effectiveness in other countries. This study recommends further research on a wider geographical perspective and exploring how these technologies might be adapted in different settings. Additionally, this study recommends further studies on the development of nurse-led strategies to improve IPC in healthcare facilities for nurses working in healthcare facilities experiencing water scarcity, particularly in resource-limited regions. This will address the limitations of these technologies in real-world settings.

Declaration of interest statement

The authors declare that they have no conflict of interest.

Acknowledgements

The authors would like to acknowledge the academic writing retreat funded by the National Research Foundation (NRF) (SARCCI190531440620-PR-2025), and the South African Medical Research Council (SAMRC) and Research Capacity Development (RCD) for funding the research project.

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